INFLUENCE OF REINFORCEMENT SCHEDULES ON RESPONSE DURATION[1]

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A previous report from this laboratory (Millenson & Hurwitz, 1960) described changes in several temporal and sequential response properties within an operant-response chain under the procedures of continuous reinforcement (CRF) and extinction. One of the temporal properties, the distribution of intervals separating the presses and releases of a lever (response duration[3]), assumed a characteristically symmetrical shape with a relatively small variance during CRF sessions in which each lever press produced reinforcement. Extinction disrupted this distribution, leading to the emission of many long intervals and a concomitant increase in the variability of the dependent variables. The lawfulness of these findings and their parallels with topographical (Antonitis, 1951) and intensive (Notterman, 1959) measures of operants invited further investigation of this response-duration variable. Described below are several experiments in which the effects of various reinforcement schedules on response duration are studied.

GENERAL METHOD

Subjects

The subjects were 12 male hooded rats, all lacking previous experimental history. In each experiment, a group of three littermates provided the data. Prior to experimentation, all animals were placed on a 22-hour hunger rhythm for at least 1 month. The animals were then habituated to the experimental chambers and trained to approach and drink milk from the dipper following the action of the dipper solenoid. After this training, the lever-press response was conditioned, and 15-minute exposure was given to CRF conditions in which each response produced reinforcement. To control for possible small differences in physical characteristics of the levers of the three boxes, each rat was assigned permanently to one of the three experimental chambers for the duration of the study. In all the experiments to be described, the rats were food-deprived for 21 ±1 hours at the beginning of the experimental session.

Apparatus

The apparatus has been described in more detail elsewhere (Millenson & Hurwitz, 1961). Briefly, it consisted of three similar sound-isolated experimental chambers, each equipped with a lever and a solenoid-operated dipper for delivering 0.05 milliliter of sweetened condensed milk, which, once delivered, remained available until consumed. A 3-gram downward force applied to the lever acting through 1 millimeter closed a microswitch. A system of timers and relays located in an adjacent room scheduled the reinforcement contingencies. Magnetic counters tabulated lever-press and reinforcement frequencies; and a cumulative recorder, which could be switched to sample the responding of any rat, monitored the time course of the behavior. In addition, the closing and opening times, and the times of the reinforcing event (all to the nearest 0.01 second ±1%) were punched on paper tape in binary coded form by a commercial unit consisting of an electronic decade counter, coincidence pulse detectors, and a translator coupled to a Creed paper-tape punch. The data tapes were subsequently submitted to computer analysis for statistical summary of certain temporal aspects of the responding including response durations. Inherent limitations in the maximum following frequency of the recording equipment made it necessary to restrict its use to the recording of the behavior of one rat at a time; therefore, in general, response durations were sampled from only a part of any single rat's session output.

EXPERIMENT I: RESPONSE DURATION AS A FUNCTION OF SIZE OF FIXED INTERVAL

The changes observed in response-duration distributions when the reinforcement schedule for lever presses is shifted from CRF to extinction parallel closely analogous changes in distributions of response loci (Antonitis, 1951) and response forces (Notterman, 1959) seen under a similar schedule shift. The correspondence between duration scores and these other measures of the ways a single operant can be made (*i.e.*, response variants) suggests the possibility of a simple relationship between response duration and these variants under many experimental conditions. This conclusion is of course not forced, since it is entirely possible that many topographies and/or forces could be associated with any given observed press-release duration. But the question remains an experimental one. At present, there is little additional

[3]In this paper, we follow Skinner's (1938) notation, calling this interval *response duration*, though more accurately it defines the duration of a sequence of behavior in which only the initial (lever-press) and terminal (lever-release) members are explicitly specified.

data permitting comparison of different response dimensions under similar procedures. Schoenfeld (1950) has suggested that increased resistance to extinction observed after partial as opposed to continuous reinforcement may be a result of an increased number of response variants being maximally strengthened in partial reinforcement. A generalization of this suggestion is the hypothesis that response variability under a schedule is correlated directly with resistance to a subsequent extinction. Thus, for example, the function relating resistance to extinction to FI (Wilson, 1954) may be attributed to the shape of the function relating the strength of the variants of the operant and FI. To date, this latter relationship is unknown. Experiment I is an empirical translation of this hypothesis, in which response durations were equated (by assumption) to response variants and strength of variants coordinated to dispersion of durations. This experiment was performed to find a function between length of FI and duration dispersion.

Method

Immediately following the preliminary training described above, Rats 12, 13, and 14 were exposed to a series of progressively increasing FI contingencies, beginning with FI 0 minute (CRF) and continuing through FI's of 0.25, 0.50, 1.00, 2.00, and 4.00 minutes. The animals were held for 10 daily sessions at each FI; and then on the immediately following session, the next longer FI schedule was introduced. During FI 0, sessions were 15 minutes long (the high rate of reinforcement leads to early satiation); at all other FI's, sessions were 40 minutes. The experiment, therefore, consisted of 60 consecutive sessions in which a schedule change occurred every 11th session. During FI 0 exposure, punched tapes were made during the 10-minute interval between the 2nd and 12th minutes. Over the remaining FI schedules, records were obtained for each rat for 10 minutes of the daily session. Data were collected from Rat 12 during the 10th–20th-minute interval; from Rat 13 from the 20th–30th-minute interval; and from Rat 14 over the 30th–40th-minute interval.

Results and Discussion

Preliminary observations of response durations under various intermittent-reinforcement procedures indicated that those durations associated with lever presses followed by reinforcement were distributed like durations observed under CRF (Millenson & Hurwitz, 1961), and were not affected by changes in schedule, deprivation, and other independent variables. These durations probably are controlled jointly by the brief delay between lever press and onset of the reinforcing complex (bell, light, magazine delivery), and the lower limit of the rat's descriminative reaction time. In the present experiment, the number of such durations associated with reinforced responses could not be controlled, their frequency varying inversely with the length of the FI. By excluding them from analysis in all schedules but FI 0 (CRF), however,

any differences in FI would not be confounded with changes in proportion of reinforced to unreinforced durations.

Before examining the unreinforced response durations as a whole, an analysis of the median response duration as a function of the ordinal number after reinforcement was made for randomly selected sessions of all animals during FI 0.25, 0.50, and 1.0 minute. Because no systematic differences could be demonstrated, homogeneity was assumed and all durations were analyzed together regardless of their temporal or ordinal position in the fixed interval.

For each record, the individual temporal intervals between each unreinforced lever press and its associated release were tabulated and then categorized into a frequency distribution with 100 adjacent 0.02-second-wide bands covering the range from 0.01 second to 2.00 seconds. Durations greater than 2.00 seconds were relegated to a final >2-second category, and their absolute value was recorded.

Figure 1 shows a number of distributions of durations obtained on Day 10 of each FI from a single rat.[4] Each plot summarizes the total emitted reinforced (FI 0) or unreinforced (all FI's >0) durations for 10 minutes of a single session, and the numbers in brackets refer to the frequency of observed durations entering into each distribution. For the purposes of these plots, adjacent bands in the categorization analysis have been combined so that the resolution here is 0.04 second. Examination of the figure reveals that except for the CRF distribution, all functions exhibit a maximum in the region of 0.30 second and are positively skewed. The skewness is pronounced, with hardly a session passing for any rat not yielding a few durations greater than 1 second, and about half the FI sessions producing an occasional duration as long as 2 or 3 seconds. Other than the marked change in shape, central tendency, and dispersion from FI 0 (CRF) to FI 15, there seems to be little systematic change in the forms of the distributions under different FI's. That particular change is also associated with a difference in the class of durations considered, and its controlling variables therefore are difficult to assign.

The emission of a few very long durations (2–4 seconds) in some sessions led to great session-to-session variability in the mean and variance of the distributions. For that reason, the median duration and a nonparametric measure of variability or dispersion, minimizing cases in the extreme tails of the distributions, were adopted. The dispersion measure is defined as

$$\frac{P_{10} - P_{90}}{2}$$

where P_{10} and P_{90} are the 10th and 90th percentiles, respectively. The measure is thus similar to the semi-

[4]The FI 15-minute record is from Day 8, as punched tapes were unavailable for this rat on Days 9 and 10 of FI 15 minutes.
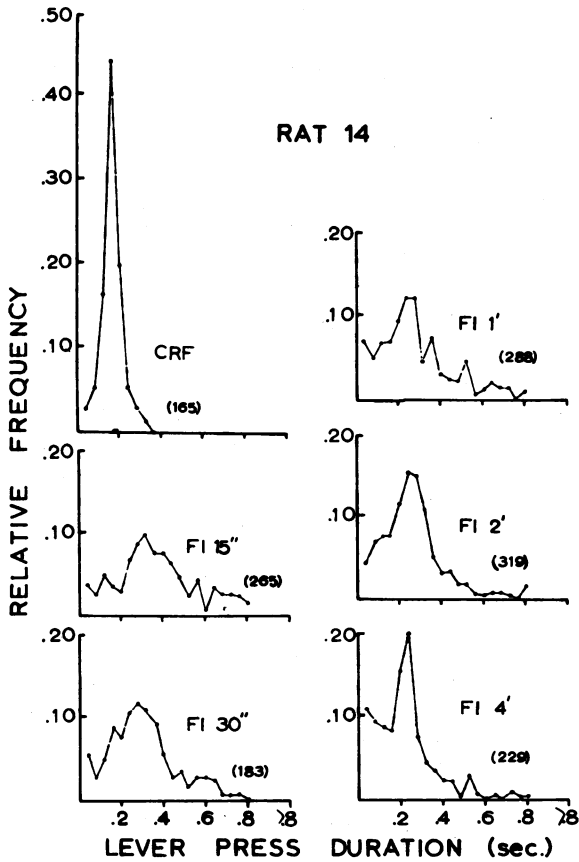
Fig. 1. Frequency functions of response durations for a single rat observed at six FI values.

interquartile range but includes more of the tails than does the SIQR.

The dispersion measure was followed over the entire experiment. The results, plotted session by session for each rat, are in Fig. 2. A number of points are missing throughout FI 0 and FI 15; during these FI values, records were not always collected for each rat. Occasional days at other FI's are also omitted because of equipment failures. There is a fair amount of "noise" in Fig. 2, but it would appear that dispersion increases abruptly with a change from FI 0 to FI 15, and for Rats 13 and 14 gradually declines throughout the remaining 50 sessions. Because many points are missing for Rat 12 during FI 15, where the derivative of this dispersion *vs.* time function seems to be changing maximally, this animal's function is particularly difficult to assess. However, from FI 30 to FI 4, dispersion appears to increase gradually. Mean and median durations and the standard deviation of the duration scores from each session were also examined. In all cases, the results were similar to those shown in Fig. 2, where dispersions are plotted. The chief difference was a greater intersession variability observed in the parametric variables.

Figure 2 gives no conclusive evidence as to the exact nature of a general relationship between response variability and FI length. There is a hint of a maximum in the data of Fig. 2 near the region of FI 30; but, as Rat 12's result shows, variability of response duration can be directly related to FI. In this connection, it should be noted that there are a variety of ways to obtain functions in which the dependent variable is some aspect of behavior and the independent variable is a schedule parameter. In the present case, the schedule parameter (FI length) was progressively increased, and each animal was exposed to 6.67 hours of each FI value. Whether or not other methods of obtaining this function yield identical results is problematic. The hypothesis that response variability as a function of FI might assume a maximum in the region of FI 1 minute was derived from FI data under procedures in which groups of animals were exposed to single FI values only. The contention that behavioral functions are dependent on the method of obtaining them is supported by the data of Fig. 3 in which the rate of response during the final 3 days on each FI schedule is plotted against FI. The
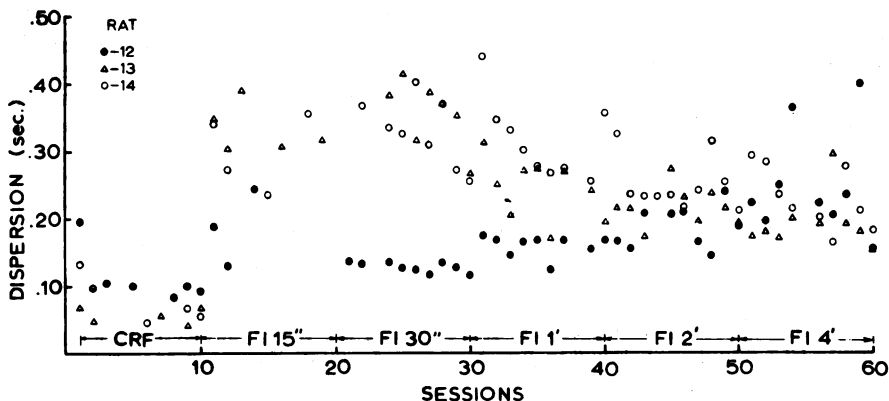

Fig. 2. Response-duration dispersions of three rats during the entire experiment.

values of the dependent variable represent corrected rates in which drinking time has been subtracted. The average drinking time per reinforcement for each rat was computed from the final few days on CRF and henceforth in FI sessions multiplied by the number of reinforcements to obtain total drinking time per session. For the purposes of calculating rates, this correction factor was subtracted from 60 minutes, the session length. The correction introduces a bias in the direction of spuriously high rates. (Under CRF, for example, it yields an infinite rate.) But where responses per reinforcement are high, the bias becomes negligible. This figure shows a slight increase in rate with increase in FI for two rats, and no change for the third animal. This result should be compared with analogous data by Wilson (1954), where the observed values of the dependent response rates are averages of groups of animals and a monotonically inverse relationship between rate and FI is obtained. On the other hand, Fig. 4 shows that the present procedure was successful in producing qualitative FI effects (Ferster & Skinner, 1957). This figure contains typical cumulative records for one rat obtained on the final days of each FI.

The changes in the response-duration distribution parameters (one of which is plotted in Fig. 2) appear more in the nature of gentle trends over the entire FI series than as abrupt changes correlated with each schedule shift, as has been reported to occur under FR manipulation (Schaefer & Steinhorst, 1959). This gradual shift in durations might well be due principally to extended exposure under intermittent-reinforcement procedures and be independent of the changes made in the FI. Experiment II, in which response durations were observed over an exposure of 60 successive sessions to an invariant FI schedule, was designed to give a partial answer to this question.

EXPERIMENT II: EXTENDED EXPOSURE TO FI 1 MINUTE

Method

Following the preliminary training described above, Rats 15, 16, and 17 were exposed to daily 15-minute CRF sessions for 10 days. From Days 5–10, punched tapes of the lever-press release durations from the 2nd–12th minutes were collected for each rat. The animals were then exposed to 60 days[5] of FI 1 minute, timed by the clock (Ferster & Skinner, 1957). During this phase of the experiment, daily sessions were 1 hour; and records were taken from Rat 15 from the 10th–20th minutes, Rat 16 from the 20th–30th minutes, and Rat 17 from the 30th–40th minutes. Thus, response-duration data were obtained from 10 minutes of each rat's hour-long run.

Results and Discussion

The time course of four behavioral measures over the 60 days of exposure to FI 1 minute are shown in Fig. 5,

plotted for individual animals. In these figures, the points are means of six consecutive sessions. The left-most two figures illustrate the changes in two parameters of the distributions of response durations obtained first during minutes 2–12 of CRF, and later the 10-minute sampling period of the hour-long FI session. For comparison with Experiment I, only unreinforced response durations enter into the calculations of the data during FI. Positive skewness of the duration distributions indicated that the median was the best measure of central tendency, and its fluctuations over the entire experiment are seen in the top-left plot. The increase in mean duration from CRF to FI 1 minute is abrupt; and though, for Rat 16, there appears to be a systematic decline in median duration throughout exposure to FI, the median remains two to three times higher than its CRF value throughout the FI exposure. Rat 15 exhibits a moderate amount of variability in its function, but may indicate a slight decrease in median duration as exposure continues. Rat 17 shows little or no change in the measure and less variability from point to point.

The dispersion measure described in Experiment I shows little or no systematic change through FI 1 minute for Rats 15 and 16. For Rat 17, however, there is a progressive rise in this measure that does not appear asymptotic by the final block of FI sessions. This discrepancy is unexplained and was correlated with a progressive increase in "graininess" of the cumulative records (not shown) of this animal.

Besides the time course of these two parameters of the response durations, the (1) response rate and (2) pause after reinforcement were also obtained during exposure to FI.

The rate is corrected as described above, and it is difficult to generalize concerning the results of the upper-right plot in Fig. 5. Rat 16 shows a large decline in rate; Rat 15 shows an increase in rate; and Rat 17's rate declines slightly. These results should be compared with those of Cumming and Schoenfeld (1960) on key-pecking rates of pigeons observed under extended exposure to an FI schedule with a limited-hold contingency.

Postreinforcement pause generally increases during the 60 days on FI 1 minute, indicating a progressive refinement of the temporal discrimination. Despite the systematic character of these curves, no significant relationship between the duration measures and either rate or postreinforcement pause can be detected. It may be concluded that during 60 hours of exposure to FI 1 minute, there are no dramatic or clearly systematic changes in the two parameters of the response-duration distributions observed here.

Frequency functions of response durations were examined throughout the FI 1-minute exposure for the three animals. Except for the usual change in form from CRF to FI, no systematic trends could be detected, and the forms of these functions were much like those seen in Fig. 1 of Experiment I.

Together, the results from Experiment I and Experiment II indicate that except for the initial change from

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[5]Rat 15 appeared unwell before Session 58, and died a few days later.
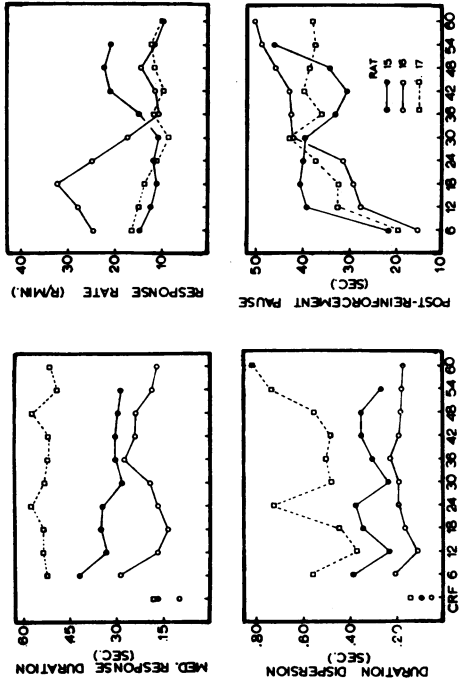
SUCCESSIVE FI SESSIONS

Fig. 5. Data for three rats showing the time course of four response measures over 60 days' exposure to FI 1 minute following 10 days of CRF conditions.
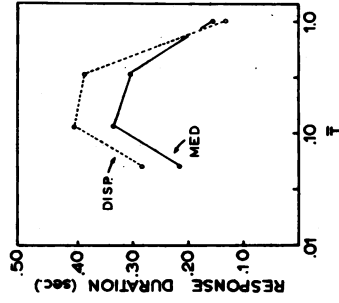

Fig. 6. Dispersion and central-tendency measures of observed-response duration distributions as a function of $\overline{T}$, the approximate reinforcement probability.
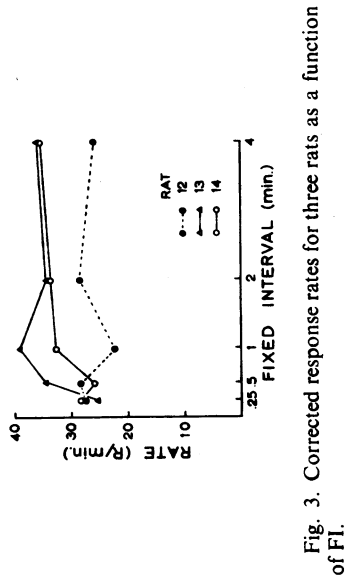

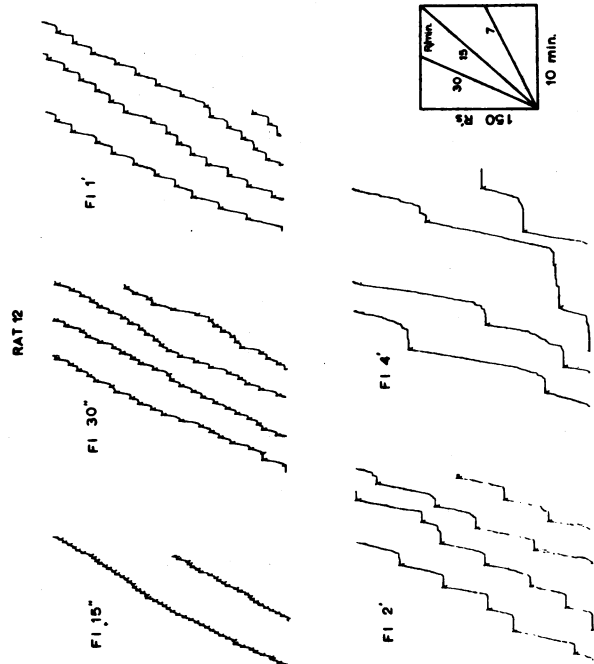Fig. 3. Corrected response rates for three rats as a function of FI.

Fig. 4. Typical cumulative-response curves for Rat 12 at each of five FI values.

CRF to FI, exposure to interval schedules leads to no marked, or even universal, effects on central tendency or dispersion of response durations, at least within the limits of exposure times used here. Some animals show trends in their duration curves as exposure progresses; but since these trends are not always in the same direction for every animal, they are not a necessary consequence of FI contingencies. The present results may be due to the inherent insensitivity of response durations to schedule changes. But it is also possible that they may be a consequence of the fact that FI schedules (in common with other classically defined reinforcement contingencies) confound both independent and dependent variables in their specification (Schoenfeld & Cumming, 1960). In such schedules, the probability of reinforcement for a given operant at any time cannot be specified in advance of the behavior itself. This lack of experimental control over FI schedules is not reflected in gross cumulative-rate curves, but it may be responsible for lack of uniform results at the level of the response variants. If so, changes in contingencies that specify more precisely the probability of reinforcement than do FI schedules might provide a measure of control over response durations. In Experiment III, the effects of a set of such schedules were used.

EXPERIMENT III: RESPONSE DURATIONS UNDER APPROXIMATELY UNIFORM PROBABILITY OF REINFORCEMENT CONTINGENCIES

Method

In addition to the apparatus described above, an adjustable, rotating shutter tachistoscope in conjunction with a photocell relay was used to generate the reinforcement contingencies in Experiment III. Rats 23, 24, and 25 were exposed to the preliminary training described above. They were then run on a series of four temporally defined schedules in which cycle length $t^D + t^\Delta = 0.3 \pm 0.1$ second, and $t^D/t^D + t^\Delta$ ($= \overline{T}$) was varied from 1.0 to 0.05. In such schedules when cycle length is of this duration, $\overline{T}$ gives approximately the probability of reinforcement for each emitted response. The animals were given five daily sessions at each of these $\overline{T}$ values: 1.0 (CRF), 0.33, 0.11, and 0.05, in that order. At $\overline{T} = 1.0$ and 0.33, sessions were 15 minutes; at 0.11 and 0.05, they were 30 minutes. Punched-tape records were collected during minutes 2–12 of $\overline{T} = 1.0$ and minutes 0–15 of the other $\overline{T}$ values.

Results and Discussion

The last 3 days of exposure to each schedule were used for the computations presented in Table 1. For each schedule and for each of the three subjects, the table contains mean values of the mean, standard deviation, median, and dispersion (as defined above) of the distributions of unreinforced-response durations (for $\overline{T} = 1.0$ [CRF], the distribution was from reinforced responses) and corrected (as above) response rates.

The correction procedure yields an infinite rate during CRF ($\overline{T} = 1.0$); the rate declines to a minimum for

Table 1*

Parameters of Central Tendency and Dispersion of Response-duration Distributions in Seconds, and Corrected Response Rates in R's per minute at four Values of $\overline{T}$.

	$\overline{T} = 1.0$			$\overline{T} = .33$		
	Rat 23	Rat 24	Rat 25	Rat 23	Rat 24	Rat 25
mean	.12	.24	.17	.33	.50	.25
σ	.12	.13	.18	.34	.45	.29
median	.09	.22	.16	.25	.37	.28
dispersion	.12	.15	.13	.33	.47	.36
R rate	∞	∞	∞	132.51	105.18	96.37
	$\overline{T} = .11$			$\overline{T} = .05$		
mean	.46	.54	.35	.27	.37	.22
σ	.44	.41	.45	.25	.28	.28
median	.33	.40	.26	.22	.32	.13
dispersion	.43	.41	.37	.26	.32	.26
R rate	48.97	53.73	38.49	89.34	96.35	94.90

*Each entry is the mean of data obtained from the last three sessions at each $\overline{T}$ value.

all the animals at $\overline{T} = 0.11$ and commences to rise again at the smallest $\overline{T}$ value (0.05) used here. This result should be compared with a function obtained by C. M. Brandauer (reported in Schoenfeld & Cumming, 1960), in which an interpolated linear *decrease* in rate between $\overline{T} = 0.10$ and 1.0 is predicted from results found under somewhat similar reinforcement contingencies. The discrepancy is probably partly artifactual and due to the method of rate correction; but because Brandauer investigated no point between 0.10 and 1.0, it is difficult to be certain that the present result may not represent a closer approximation to the actual function between those points.

The central tendency and dispersion measures of response duration all consistently show a maximum at one of the intermediate $\overline{T}$ values (typically $\overline{T} = 0.11$). Skewness of these distributions, roughly indicated by the mean minus the median, also passes through a maximum near this point. Averaging of the data seemed justified since the form of the functions was similar for all animals, and a group function relating response-duration dispersion and median to $\overline{T}$ is presented in Fig. 6. This figure reveals the nature of these functions and shows clearly the marked correlation between central tendency and dispersion measures, typical of response durations generally. When the results for response rate are compared with those in Fig. 6, a rough negative correlation between rate and duration is established. The correlation is not perfect, however, and the changes in rate cannot be wholly explained by duration fluctuations.

Duration-frequency functions for the three rats on the final day at each schedule (except CRF) are shown in Fig. 7. The $\bar{T}$ is labeled, and the number in brackets refers to the number of unreinforced durations in the distribution. The CRF functions are not shown because they resemble those reported elsewhere (Millenson & Hurwitz, 1961; also, Fig. 1 above). The functions of Fig. 7 illustrate the typical features of unreinforced durations in general—a maximum at about 0.3 second, and a long, positively skewed tail. But, in addition, they in some cases show a high incidence of very short-response durations, correlated with frequent response bursts generated by some of the present schedules. The plot of Rat 25, $\bar{T} = 0.05$, in particular, shows a distribution in which 40% of the emitted responses are less than 0.05 second.
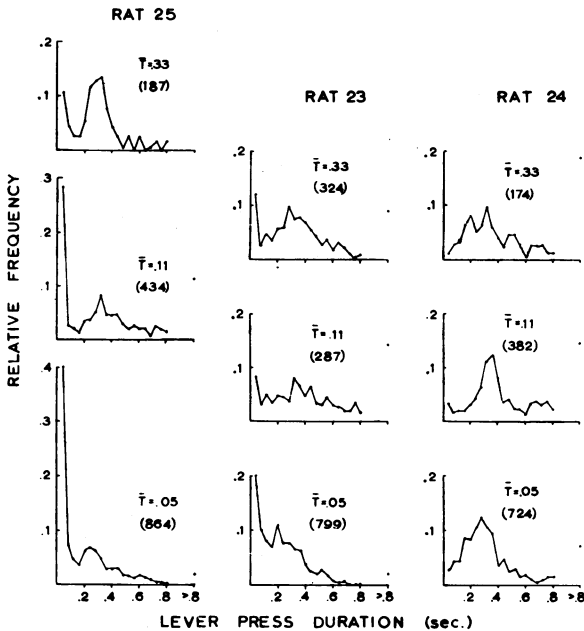

Fig. 7. Frequency functions of response durations of Rats 25, 26, and 27 taken on the final day at three $\bar{T}$ values.

The consistency of the results in Experiment III suggests that these contingencies do provide a more accurate control over behavior than do the FI schedules of Experiments I and II. Whether this is a general principle characterizing temporally defined schedules or whether this particular set of contingencies is a special case remains to be seen. There is of course the fact that behavior under these schedules of Experiment III is free from any systematic temporal discriminations, with cumulative-response records (not shown here) depicting a relatively high and constant rate; and it may be that classical schedules that show a similar rate picture control durations equally as well.

EXPERIMENT IV: RESPONSE DURATIONS UNDER 5-1 FIXED-RATIO CONTINGENCIES

During some preliminaries to other experimental work, the opportunity was afforded to examine response durations when lever-pressing behavior was being maintained under 5-1 fixed-ratio (FR 5) contingencies. A summary of the duration effects under these conditions is presented here.

Method

Rats 26, 27, and 28 were exposed to the usual preliminary training and then shifted to an intermittent-reinforcement procedure that delivered milk following every fifth lever press. The animals were run on this FR 5 procedure for 15 half-hour sessions. On Sessions 10, 11, 13, 14, and 15, punched-tape records of responding of each rat were collected from the first 20 minutes of the session.

Results and Discussion

Table 2 exhibits median response durations and dispersions as well as IRT means and standard deviations averaged over the 5 days during which records were made. The data have been classed according to the ordinal number between reinforcements. Inspection of the duration medians and dispersions reveal no "goal gradient" or other clearcut trends within the chain of five lever presses. The decline in mean IRT for Rats 26 and 27 as a function of ordinal number indicate that "scalloping" may occur even at this small FR, though it was not visible on the cumulative kymograph curves. Rat 28, however, shows no evidence of this effect.

When the actual frequency functions of lever-press durations under FR are examined, they show a rel-

Table 2

Means and Standard Deviations of the Five Inter-reinforcement IRT's in Seconds, and Median Response Durations and Duration Dispersions of the Five Inter-reinforcement Responses in Seconds

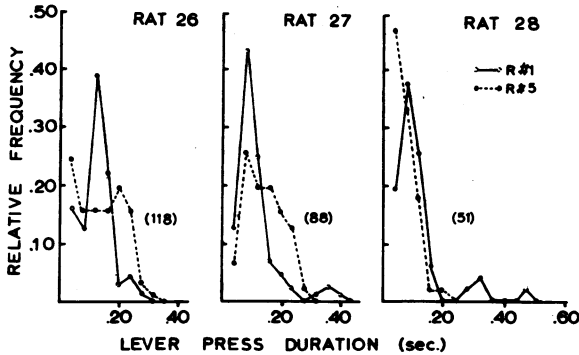| Animal		Ordinal Number After Reinforcement				
		1	2	3	4	5
Rat 26	Mean IRT	3.26	.40	.14	.13	.15
	σ	1.76	.19	.04	.02	.01
	Med. Duration	.14	.09	.14	.17	.17
	Dispersion	.09	.12	.17	.22	.11
Rat 27	Mean IRT	6.25	.33	.14	.20	.26
	σ	3.02	.17	.04	.02	.01
	Med. Duration	.14	.13	.12	.14	.14
	Dispersion	.13	.12	.12	.15	.09
Rat 28	Mean IRT	5.82	.18	.23	.22	.33
	σ	5.52	.21	.05	.02	.01
	Med. Duration	.08	.10	.11	.08	.06
	Dispersion	.11	.10	.11	.11	.06

Fig. 8. Session 15 frequency functions of response durations for three rats under FR 5. Solid lines, open circles define functions associated with the first response in the ratio; dashed lines, filled circles define functions associated with the fifth and final response in the ratio.

atively low mean and variance, like the CRF functions (*cf.*, also, Schaefer & Steinhorst, 1959); but they lack the symmetry of the distributions associated with CRF. Figure 8 shows distributions of durations of all three rats on Day 15. The open points connected by solid lines represent relative frequencies of the first response in the FR chain; the solid points connected by dashed lines represent relative frequencies of the fifth and last response in the FR chain. The numbers in brackets refer to the number of complete FR chains in the distributions. Differences in form between distributions of the first and fifth lever-press duration distributions are present, but it is difficult to generalize about their nature. Distributions for the second, third, and fourth presses (not shown here) take similar forms, though no one shape is characteristic of any one particular ordinal position. It seems a fair conclusion that under FR 5, at any rate, duration measures reveal no systematic intrachain differences.

SUMMARY AND CONCLUSIONS

A series of experiments is reported in which the durations of lever-press behavior of rats are studied under different schedules of milk reinforcement. The following conclusions seem warranted:

(1) When rats are exposed to FI contingencies following CRF, unreinforced responses are emitted, and the central tendency and dispersion of the durations of these responses remains two to three times higher than the corresponding values under CRF.

(2) Extended exposure to FI schedules (progressively increasing in length, or invariant) may yield trends in the response-duration parameters, but the results are not consistent from animal to animal.

(3) When contingencies which specify an approximately uniform probability of reinforcement for any given response are systematically varied, duration parameters appear to pass through a maximum at probability of reinforcement equal to 0.11.

(4) Under 5–1 fixed-ratio reinforcement, asymmetrical duration distributions are obtained which show a narrow dispersion and a low median. No systematic differences in response durations within the FR chain could be detected.

(5) The failure of several of the present contingencies to exert precise control over response durations indicates caution in interpreting such durations as measures of operant-response variants.

REFERENCES

Antonitis, J. J. Response variability in the white rat during conditioning, extinction, and reconditioning. *J. exp. Psychol.*, 1951, **42**, 273–281.

Cumming, W. W., and Schoenfeld, W. N. Behavior stability under extended exposure to a time-correlated reinforcement contingency. *J. exp. anal. Behav.*, 1960, **3**, 71–82.

Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement.* New York: Appleton-Century-Crofts, 1957.

Millenson, J. R., and Hurwitz, H. M. B. Some temporal and structural properties of behavior during conditioning and extinction. *J. exp. anal. Behav.*, 1961, **4**, 97–106.

Notterman, J. M. Force emission during bar pressing. *J. exp. Psychol.*, 1959, **58**, 341–347.

Schaefer, H. H., and Steinhorst, R. A. The effect of changing the schedule of reinforcement upon duration of responding. *J. exp. anal. Behav.*, 1959, **2**, 335–341.

Schoenfeld, W. N. On the differences in resistance to extinction following regular and periodic reinforcement. *C.E.A.B. Note No. 20*, February 27, 1950.

Schoenfeld, W. N., and Cumming, W. W. Studies in a temporal classification of reinforcement schedules: summary and projection. *Proc. nat. acad. Sci.*, 1960, **46**, 753–758.

Skinner, B. F. *The behavior of organisms.* New York: Appleton-Century Co., 1938.

Wilson, M. P. Periodic reinforcement interval and number of periodic reinforcements as parameters of response strength. *J. comp. physiol. Psychol.*, 1954, **47**, 51–56.